Improving Stormwater Program Monitoring, Evaluation, Tracking, and Reporting

Workshop Report and Recommendations

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Prepared for:

U.S. Environmental Protection Agency
Region 9

75 Hawthorne Street
San Francisco, CA 94105

Prepared by:

PG Environmental

14555 Avion Parkway, Suite 125
Chantilly, VA 20151

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Special thanks must also be extended to the workshop participants from across the country who energetically and thoughtfully engaged in the workshop and in the preparation of this report.

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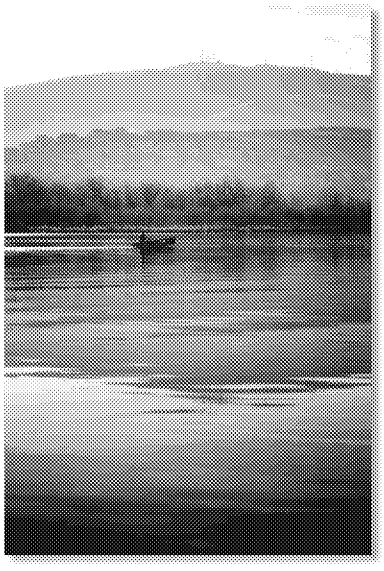
EXECUTIVE SUMMARY



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Without proper treatment, urban stormwater runoff can convey pollutants into local waterbodies, threatening human health, public water supplies, and aquatic habitats, and possibly deterring economic activities. The U.S. Environmental Protection Agency (EPA) established the Municipal Separate Storm Sewer System (MS4) program in the early 1990s under its National Pollutant Discharge Elimination System (NPDES) to address pollution from urban stormwater runoff. Now almost 30 years later, regulators and permittees have a greater understanding of urban water quality management, have compiled illustrative examples of program successes and failures, and are using new technologies for data management, modeling, and water quality monitoring.

While the MS4 program has evolved over the decades in response to new information and tools, significant opportunities for improvement remain, especially around stormwater program monitoring and assessment. A more strategic approach to monitoring and assessment, including the use of newer technologies, could enable decision-makers to shift resources from less productive approaches to the most useful, cost-effective ones.

In March 2018, EPA Region 9, with assistance from EPA Headquarters and in partnership with the State of California, invited 31 stormwater experts from across the country to Oakland, California, for a two-day workshop titled *Improving Stormwater Permit Approaches to Monitoring, Tracking, Evaluation, and Reporting*. Participants included representatives from EPA, state Clean Water Act permitting agencies, local stormwater programs, national associations, consulting firms, and nonprofit organizations. The workshop was designed to explore current requirements and practices for municipal stormwater program monitoring, evaluation, tracking, and reporting and identify opportunities for improvement that would support more effective program implementation.

This report aims to provide a synthesis of participant ideas and contributions, along with other existing research, to identify the most promising opportunities for strengthening MS4 permits and program implementation. It includes an overview of the workshop discussions, specific recommended actions, case studies, summaries of known efforts related to the recommendations, and, where possible, some indication of commitment by stakeholder groups or organizations (e.g., trade associations, permittees, states, universities) to make progress in a given area. The table on the following page presents a brief synopsis of the recommendations.

EPA, the State of California, and participating organizations plan to build on workshop conversations through broad outreach to partners and stakeholders and continued dialogues surrounding these important issues. This iterative, inclusive approach allows for (1) more thorough evaluation of stormwater program monitoring, evaluation, tracking, and reporting provisions; (2) assessment of opportunities to adjust programs to better meet clean water goals; and (3) identification of specific actions necessary to enable innovative and effective approaches across the nation.

SUMMARY OF WORKSHOP RECOMMENDATIONS

General Capacity Building and Program Support

- **Develop a vision for the future of stormwater monitoring to improve MS4 program efficiency and effectiveness.** Identify common attributes of an effective approach to stormwater monitoring that support other local evaluation, tracking, and reporting efforts. (Section 3.1.1)
- **Develop a guide to monitoring and evaluation to better serve MS4 programs.** Document examples of successful monitoring approaches to enhance efficiency in local program design and implementation. (Section 3.1.2)
- **Establish key performance metrics (activity- and outcome-based) for MS4 programs.** Provide guidance and examples on approaches for measuring and communicating how program activities impact water quality outcomes. (Section 3.1.3)
- **Identify ways to leverage existing data sets to improve MS4 program management decisions.** Transform existing stormwater data into actionable information through better data analytics tools and broader scale evaluation of annual reports. (Section 3.1.4)

Improving Permitting Strategies

- **Improve clarity of monitoring and effectiveness permit requirements (including objectives, methods, and designs).** Compile examples of permit designs for monitoring requirements to illustrate the range of approaches and encourage the adoption of best practices. (Section 3.2.1)
- **Create a pathway in permits to make special studies or targeted monitoring more impactful.** Design special studies and other stormwater methods assessments so that the results inform the local program while also benefiting the larger community of MS4s. (Section 3.2.2)
- **Evaluate whether lack of 40 CFR Part 136 approval presents a barrier to implementing new technologies for water quality sampling and analysis.** Assess barriers and issues with using new water quality monitoring technologies that lack approved sampling and analysis methods. (Section 3.2.3)

Making Outfall and Receiving Water Monitoring More Discriminating to Inform Program Management

- **Evaluate appropriate scale for monitoring efforts to yield actionable results.** Identify options for structuring monitoring to account for different geographical and temporal scales of concern to answer key management questions while also seeking to maximize the opportunity for comparability, information sharing, and technology transfer. (Section 3.3.1)
- **Convene a visioning session for deploying sensors in MS4 programs.** Give municipal stormwater programs improved platforms for sharing information about new sensor technologies and best practices for water quality monitoring. (Section 3.3.2)

Improving Our Ability to Quantify Effectiveness—Approaches to Link Water Quality Outcomes to Actions

- **Document the current state of knowledge of BMP performance and effectiveness.** Increase MS4 program capacity by generating and disseminating data to help quantify the effectiveness of stormwater best management practices in addressing various pollutants in different settings. (Section 3.4.1)
- **Improve the applicability and usefulness of modeling through collecting and incorporating better performance data.** Strengthen long-term stormwater planning and project siting decisions by improving water quality and siting models to better address all factors contributing to pollutant reduction. (Section 3.4.2)
- **Evaluate methods to account for true source controls in models.** Develop guidance to assist in development and implementation of modeling approaches to account for true source control methods for key stormwater pollutants of concern. (Section 3.4.3)

Improving Program Tracking and Reporting

- **Identify an approach for using established performance metrics to guide tracking and reporting efforts.** Adopt a dynamic and integrated tracking, evaluation, and reporting system that synthesizes data geographically and supports real-time management decision-making. (Section 3.5.1)
- **Determine the most effective MS4 program reporting mechanisms and formats.** Implement a web-based reporting template informed by stakeholder input to streamline regulatory requirements and promote knowledge transfer across different states and local MS4 programs. (Section 3.5.2)

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ABBREVIATIONS AND ACRONYMS

BMP	best management practice
CASQA	California Stormwater Quality Association
CFR	Code of Federal Regulations
EPA	U.S. Environmental Protection Agency
MCM	minimum control measure
MS4	Municipal Separate Storm Sewer System
NMSA	National Municipal Stormwater Alliance
NPDES	National Pollutant Discharge Elimination System
O&M	operations and maintenance
POC	pollutants of concern
RAA	reasonable assurance analysis
SMC	Southern California Stormwater Monitoring Coalition
SWMP	stormwater management program
TMDL	total maximum daily load
WEF	Water Environment Federation
WQS	water quality standards

A Note on Terminology Used at the Workshop

Different terminology used by local programs and regulators across the country necessitated the use of a common set of terms during the workshop and in this report. These terms and definitions may not be applicable in all other contexts.

Workshop participants extensively discussed the pros and cons of two ways to assess MS4 programs and their components:

- Use of water quality or other response monitoring data.
- Evaluation of program activities and best management practices (BMPs).

Accordingly, this report distinguishes between water quality and other environmental "monitoring" and program activity and BMP "evaluation," even though it is understood that these approaches may overlap in practice. The report also uses particular definitions of "activities" and "BMPs," two terms that different participants used in different ways during the workshop itself. The report's definitions are presented below.

- **Monitoring:** Collection of water quality and other environmental data—in a watershed, within the collection system, at end-of-pipe, or in a receiving water—that aids in analyzing program effectiveness or answering other management questions.
- **Evaluation:** An analysis of non-water-quality/environmental data and information about activity and BMP implementation that aids in determining whether a program, program element, activity, or individual BMP is meeting its intended objectives, or in answering other management questions.
- **Tracking:** Compiling and managing data and information (including the use of electronic databases and other systems to document program information).
- **Reporting:** Presenting information to regulatory agencies or other stakeholders to demonstrate program implementation or effectiveness.
- **Assessment:** An analysis of the overall effectiveness of an MS4 program; can be improved with information from monitoring and/or evaluation.
- **BMPs:** In the narrower sense used in this report, structural treatment or source control measures that are intended to result in measurable water quality outcomes.
- **Activities:** In the narrower sense used in this report, other program implementation actions (e.g., public education and participation, facility site inspections) that primarily result in outputs rather than immediately measurable water quality outcomes.

The intent in distinguishing these terms was to emphasize the importance of collecting and assessing different types of data and information necessary to inform assessments of the effectiveness of *all* facets of MS4 program implementation.

INTRODUCTION

Photo: EPA

MS4 programs are often inherently complex for multiple reasons—including large geographic areas, many pollutant sources, a mix of program activities and BMPs, transport of stormwater flows above and below ground in natural and manmade systems—and "stormwater program managers find themselves facing increasing pressure to demonstrate the effectiveness of their programs" (CASQA, 2015). This pressure comes both from regulatory agencies (which focus on assessing compliance with regulatory requirements) and local program managers, elected officials, and funders (who focus on services and their perceived value to the public). Further, local programs' ability to carry out MS4 program requirements is often resource-constrained, making it increasingly vital to prioritize activities with outcomes that serve the community and environment. However, local program capacity to identify improved methods for assessing program actions and identifying the most effective implementation strategies remains limited.

MS4 permitting authorities play a key role in determining how MS4 programs must conduct monitoring, evaluation, tracking, and reporting. Many permitting authorities are understaffed, underfunded, or lacking in technical expertise concerning design of program assessment methods. As a result, many states have limited capacity to work with permittees to improve monitoring and evaluation approaches and associated permit requirements. In many cases, states also devote little effort to evaluating data and information collected and reported by permittees. Any initiative to improve MS4 assessment frameworks will require engagement both by permittees and permitting authorities, informed by careful analysis of past "lessons learned" in program implementation and analysis.

As the term "effectiveness" is not explicitly defined in the Clean Water Act or EPA regulations, it has proven particularly difficult to demonstrate—one of the largest problems facing the national MS4 program. Much time and money is spent on monitoring efforts that are not designed to answer key questions about program effectiveness or guide program improvement.

While the MS4 program has evolved in response to new information and tools, significant opportunities for improvement remain. EPA convened a small group of stakeholders in late 2017 to assess the MS4 program at large and identify the most impactful opportunities for strengthening permits and building program capacity. This report presents the discussions and ideas from a follow-on workshop EPA held in March 2018 that focused on approaches to monitoring, tracking, evaluation, and reporting.

The workshop featured stormwater experts from across the country, but a majority of its participants were from California. As a result, its deliberations and findings may overly represent issues, approaches, and perspectives developed in that state.

In December 2017, EPA convened a workshop on MS4 program minimum control measures, industrial program requirements, and water-quality-based control requirements. The resultant white paper, *Evolution of Stormwater Permitting and Program Implementation Approaches* (EPA, 2018), captures workshop discussion and recommendations for program improvement and provides background information on the overall MS4 program.

With no standardized approach to assessing program effectiveness across the country, workshop participants concurred, there is an opportunity to create a better mix of water quality monitoring, evaluation, tracking, and reporting requirements that will strengthen links between program assessment and management decisions. Several participants believed that similar convenings in other parts of the country would identify opportunities to improve MS4 program implementation, assessment, and permitting in ways that are sensitive to regional differences in program evolution and approaches.

> "Monitoring should be a way to change incrementally the standard—not punish the willing. Management and permitting actions must evolve as experience leads to opportunities for improved practice and better-informed expectations" (WEF, 2015).

This report synthesizes workshop participants' ideas for improvements to monitoring, evaluation, tracking, and reporting along with other existing research. Section 3 presents the full set of recommendations, accompanied by discussion overview, related actions, case studies, and, where possible, some indication of commitment by stakeholder groups or organizations (e.g., trade associations, permittees, states, universities) to make progress in a given area. Inclusion of a recommendation in this report does not necessarily indicate the support of all workshop participants; rather, it is intended to stimulate further discussion, inquiry, and possible progress.

1 MS4 Workshop

In March 2018, EPA Region 9, with assistance from EPA Headquarters and in partnership with the State of California, invited 31 stormwater experts from across the country to Oakland, California, for a two-day workshop titled *Improving Stormwater Permit Approaches to Monitoring, Evaluation, Tracking, and Reporting*. The workshop was designed to explore current requirements and practices for municipal stormwater program monitoring, evaluation, tracking, and reporting and identify opportunities for improvement that would support more effective program implementation. Its primary goals were to identify (1) how permits can direct or incentivize these improvements, (2) what methods could be used to support these improvements (e.g., training, guidance, identification of best practices, research), and (3) what entities within the sector could help effect these improvements in permitting and program practice.

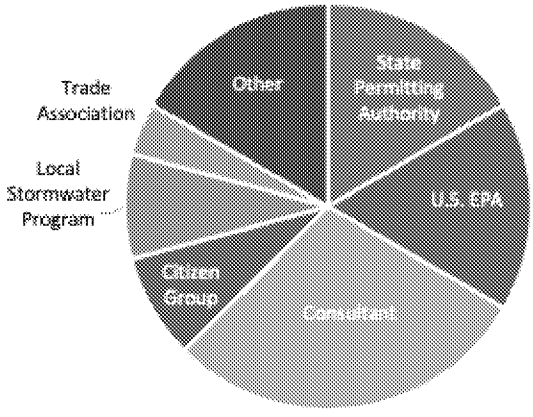


Figure 1. Distribution of workshop participants across the sector.

Through facilitated dialogues, invited representatives from federal, state, and local government, as well as sector stakeholders (e.g., permit holders, trade associations, citizen groups, and academia), evaluated MS4 program monitoring, evaluation, tracking, and reporting approaches to inform possible changes in NPDES permit provisions and identify opportunities to improve MS4 programs. To promote honesty and openness, participants agreed that the viewpoints expressed

would not be attributed to individuals in this resultant report. (A full list of workshop participants is included in Appendix A.)

As noted above, this workshop was a follow-on to a prior event that focused on MS4 program minimum control measures (MCMs), post-construction program requirements, and water quality-based control requirements. The white paper for that first workshop, *Evolution of Stormwater Permitting and Program Implementation Approaches*, captures discussion and recommendations for program improvement and provides background information on the overall MS4 program. This report does not duplicate that background information; instead it focuses directly on the workshop discussions and recommendations for improvement to monitoring, tracking, evaluation, and reporting.

1.1 Workshop Format

The workshop included seven sessions over two days in a format designed to identify recommendations specific to monitoring, evaluation, tracking, and reporting approaches (full agenda included in Appendix B). Each workshop session had the same general structure: a conversation starter, facilitated group discussion, and identification of important findings and specific actions to strengthen and improve approaches to monitoring, tracking, evaluation, and reporting.

Workshop Sessions

1. Current Condition—Are Current Monitoring, Evaluation, Tracking, and Reporting Requirements Effective?
2. How Can We Better Use Performance Metrics to Facilitate Improved Monitoring, Tracking, Evaluation, and Reporting?
3. How Can We Make Outfall and Receiving Water Monitoring More Useful?
4. Linking Activities to Expected Water Quality Outcomes
5. How Can We Improve Program Performance Tracking?
6. Reforming Reporting Approaches to Help Move Programs Forward and Give Permitting Authorities What They Need
7. Reflection, Synthesis, and Wrap-Up

This report captures the essence of these conversations so that others may benefit from the collective expertise. EPA plans to continue working with various partners and stakeholders to refine and implement the most promising ideas for strengthening MS4 programs through improved monitoring, tracking, evaluation, and reporting and enabling new, innovative permitting approaches.

1.2 Pre-Workshop Questionnaire

In advance of the workshop, participants were polled to gauge their attitudes toward specific aspects of the permitting program by responding to a series of hypotheses. Twenty-four submissions were received in total. Respondents overwhelmingly agreed that there was potential to realize cost-effective positive environmental outcomes through better approaches to monitoring, tracking, evaluation, and reporting.[1]

[1] Participants could also respond "no opinion or insufficient knowledge."

Table 1. Response to the pre-workshop questionnaire rating the potential for significant improvement toward cost-effective environmental outcomes for each element.

	Significant or Some Potential	Little or No Potential
Water quality monitoring *(receiving water, outfall, within collection system, at project or practice scale)*	100 percent	—
Non-water-quality evaluation *(activity evaluation, effectiveness evaluation)*	88 percent	8 percent
Tracking *(tracking discrete activities [e.g., inspections, street sweeping, BMP installation], active asset management planning and tracking)*	100 percent	—
Reporting *(annual reporting to permit authorities, reporting to public or elected officials)*	88 percent	12 percent

The survey also sought participants' reactions to a series of hypothesis statements to help determine the degree of alignment in opinions before the meeting. There was strong support for many statements on the pre-workshop questionnaire, which helped frame onsite discussion and can help orient further consideration of changes in monitoring, tracking, evaluation, and reporting. Select statements are rated below.

Table 2. Responses to select hypothesis statements in the pre-workshop questionnaire.

	Strongly Agree or Agree	Strongly Disagree or Disagree
Monitoring designs must go beyond just data collection methods to include data management, data analysis, and reporting formats that clearly link data collected with performance metrics.	100 percent	—
Performance metrics need to be established in concert with improved monitoring designs and methods.	96 percent	—
Metrics should enable evaluation not just of what was done, but also of whether those actions were effective.	96 percent	—
No one monitoring and evaluation method addresses all the assessment needs; multiple approaches tailored to local circumstances are needed.	92 percent	4 percent
Better guidance and training on new reporting frameworks and how to incorporate them in permits will be needed to advance reporting approaches at the state and local levels.	92 percent	4 percent

Respondents provided further insights and suggestions through the pre-workshop questionnaire. One recurring theme was that assessing effectiveness cannot be accomplished through a "one size fits all" approach. Two respondents captured these sentiments as follows:

> *"There isn't one right answer for every program, but there must be a better monitoring/tracking/ assessment framework that could be used to build more effective programs across the country."*

> *"Effectiveness assessment is element-specific. No one measurement fits all. So, rather than specifying a measurement, specify a process to follow between the different elements to identify the appropriate measurement, etc. Process would be something like:* ***Inquiry*** *(question, permit requirement, exceedance)* → ***Pollutants of concern (POC)*** → ***BMP*** → ***Effectiveness measurement*** → ***Effectiveness methodology*** → ***Report.****"*

Additional questionnaire findings are incorporated throughout the report, where applicable; Appendix C summarizes questionnaire results.

1.3 Defining "Effectiveness"

A purpose of the workshop was to explore the concept of "effectiveness" and how MS4 programs and permits can be improved to orient monitoring, evaluation, tracking, and reporting towards demonstrating effectiveness. While many MS4 permits require local programs to evaluate the effectiveness of their efforts, there is significant ambiguity around what "effectiveness" means for MS4 programs—is it a measurable water quality outcome? Completion of required activities? Achievement of other co-benefits[2] through infrastructure improvements? Or a combination of these?

Participants at the December 2017 and March 2018 workshops were asked to describe the key elements of MS4 program effectiveness; common themes emerged, but there was significant variation in the responses. Based on responses from the pre-workshop questionnaire, key elements include:

- A clear definition of performance metrics (or measures) using common objectives and concise language.
- Results such as enhanced awareness and behavioral change.
- Reduction in urban stormwater pollution and mitigation of the impact on receiving waters.
- Tracking progress to ensure accountability of outcomes.
- An ability to measure and communicate quantifiable outcomes and benefits to communities.

"**Effectiveness Assessment** consists of the methods and activities that managers use to evaluate how well their programs are working and to identify modifications necessary to improve results" (CASQA, 2015).

[2] For example, reduction in flood risk, improvement in urban aesthetics and amenities through the use of green infrastructure, and water supply augmentation.

These select responses from the pre-workshop questionnaire describe **key elements of MS4 program effectiveness**:

> *"Clear and measurable performance metrics and the ability to gauge activities and actions versus those metrics."*
>
> *"Ability to establish a relationship between the BMP/action/activity and a reduction in pollutant loads."*
>
> *"Ability to show water quality improvement, behavior change, and an overall understanding of the benefits and challenges associated with urban stormwater."*

Given the variation in responses and known difficulty in defining effectiveness, this report does not attempt to create a single definition—or suggest that a single definition is feasible or needed. Rather, defining and determining effectiveness should occur at the permit, local, or regional scale and be based on the unique conditions, objectives, and resources of the area. Additionally, limitations in the ability for monitoring to effectively and efficiently determine effectiveness must be considered. Throughout this report, the authors highlight various and situationally unique definitions of effectiveness. These show the various applications of effectiveness within the context of MS4 programs and how monitoring, evaluation, tracking, and reporting could be improved to facilitate a determination of effectiveness.

Workshop participants also wanted to address a common misconception that effectiveness is mostly synonymous with compliance. For example, a MS4 program could be compliant with its discharge permit but not effective in addressing local or regional water quality problems, producing desirable co-benefits, or meeting other objectives.

2 Overview of Current (and Past) Monitoring and Assessment Approaches and Efforts

Currently, permittees and regulatory agencies often evaluate program effectiveness through a combination of monitoring, evaluation, tracking, and reporting efforts. Though these requirements in MS4 permits are intended to enable iterative improvements, many local programs do not systematically use their data in this way. Moreover, regulatory agencies often do not make full use of reported data and information to assess permit compliance or to tailor future permit requirements to better meet information needs.

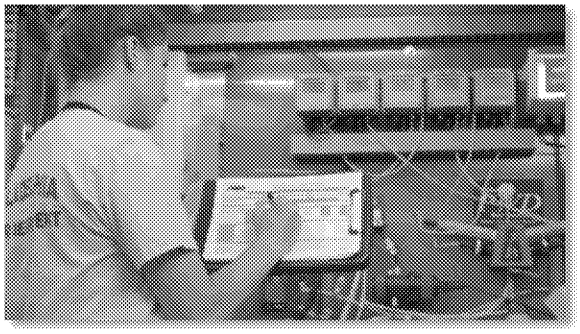


Photo: EPA

Stakeholders at the March 2018 workshop were asked to consider improvements to monitoring, tracking, evaluation, and reporting. As a backdrop for these workshop discussions, there was acknowledgement that many current approaches may not enable local program managers to detect water quality changes and correlate MS4 program actions with outcomes. There are also many instances where new requirements have been added to permits without careful consideration of how performance should be evaluated, and program actions adjusted over time. This has increased the resources needed for monitoring, tracking, and/or reporting efforts and resulted in often lengthy and intense reporting efforts for permittees with little perceived benefit to the permittee, regulator, or water quality.

Note, though, that there are diverse views on the need to improve stormwater monitoring, tracking, evaluation, and reporting. Some believe their MS4 programs are stable and reasonably effective, and therefore, not in need of significant updating.

2.1 Variation in Approaches

The national MS4 program was rolled out in two phases: Phase I targeted medium and large communities and industrial facilities, while Phase II addressed smaller communities and other non-municipal entities. Both Phase I and Phase II regulations require permittees to assess their stormwater control measures (i.e., BMPs) and perform some level of reporting to regulatory authorities. However, variability within the regulations and differences in priorities of permitting authorities have led to significant variation in the way monitoring, evaluation, tracking, and reporting requirements are represented in permits and subsequently met by permittees. For example, Phase I regulations require permittees to develop a monitoring program, and larger MS4s may have requirements that necessitate sophisticated sampling programs with annual expenditures of over $1 million. While the Phase II program allows for monitoring, it does not require it; as a result, some MS4 permits may not require any monitoring program at all (EPA, 2010a). Furthermore, some authorities have taken markedly different approaches to permitting (and associated monitoring and evaluation provisions) for each category of MS4 permits.

Workshop attendees indicated that the costs of stormwater monitoring and evaluation (and associated tracking and reporting mechanisms) are poorly understood. Across the United States,

MS4 program investments in monitoring and program evaluation vary a great deal, reflecting the wide diversity of municipal stormwater systems, water quality issues, and regulatory requirements. Without better information on the costs of alternative monitoring, evaluation, tracking, and reporting approaches, it will be difficult to make appropriate changes in how we assess program effectiveness and adjust program management. Several participants urged a more focused effort to evaluate costs of different program assessment frameworks to help identify cost-effective opportunities for improvement.

EPA's white paper from the 2017 workshop provides background on MS4 program changes over time. It describes a general progression from an initial focus on MCMs to more focus on post-construction stormwater management and low impact development, and then to an increased focus on water quality-based and total maximum daily load (TMDL) requirements. The tools and approaches for capturing, tracking, and reporting information have also evolved and currently range from hardcopy maps and documents to sophisticated geographic information system–based mapping, asset management software, and modeling. Furthermore, permittees are using different approaches to water quality monitoring and program evaluation at different scales and with different technologies.

2.2 Examples of Approaches

The following list presents several examples of different monitoring and evaluation approaches from across the country.

- Through its principal permittee and a regional monitoring group, **Los Angeles County MS4 permittees** monitor receiving waters and in-system locations for some design storms. Cause and effect connections are inferred between actions taken in the monitored watershed and water quality responses. Modeling (based on estimated effectiveness for existing BMPs and anticipated load reductions for new BMPs) is also used by permittees to estimate the likely overall effect of BMP implementation within watersheds and assist BMP targeting. The Los Angeles County MS4 permit gives permittees flexibility in designing integrated monitoring programs that leverage resources for multiple benefits and collect data from representative locations.
- **Minnesota Phase II MS4 permittees** are encouraged to focus on implementation of minimum measures and not required to conduct monitoring. The State of Minnesota administers a statewide surface water monitoring program funded by a voter-supported measure. It is assumed that recommended BMPs and other implementation actions are effective and that there is a positive correlation between MS4 program implementation actions and water quality benefits.
- **Washington, D.C.**, has used geographically targeted BMP implementation and monitoring to detect "signals" in water quality change based on intensive implementation of green infrastructure BMPs in the specified area. Information gained at the smaller scale is extrapolated to evaluate larger-scale implementation. The efforts include interim measurable milestones so the evaluation timeline is constrained.
- The **City of Salinas** in California's Central Coast region has experienced an evolution of approaches since 2005, when there was a weak connection between water quality monitoring and program effectiveness. The program has moved from trying to assess the effectiveness of different program activities to focusing more on treatment control BMP assessment and

outfall load-based monitoring at several locations. This effort has been coupled with a web-based dashboard for tracking progress, guiding adaptation, and providing information to regulators.

Workshop participants recognized that monitoring is conducted for different purposes and that monitoring designs can and should vary accordingly.

- For example, **compliance**-related monitoring is often wider in geographical scope but shallower in coverage. This type of monitoring is conducted by many, if not most, permittees. During the workshop, there was extensive discussion of whether the "wide but shallow" approach to compliance monitoring supports effective, discriminating program assessments.
- In contrast, BMP **effectiveness** evaluation is usually conducted in fewer (but hopefully representative) locations in greater depth. This type of evaluation can be conducted by different organizations but is done with the understanding that it need not be repeated by every permittee if it was well-designed at the outset. Attendees discussed whether existing BMP effectiveness evaluation to date provided enough information about BMP performance in addressing different settings and pollutants.
- Finally, workshop attendees also discussed water quality **trend** monitoring. Trend monitoring may be related to compliance monitoring. Participants noted that associating changes in water quality with changes in stormwater management practices and actions is desirable but analytically very challenging from a monitoring design standpoint.

During the workshop, participants generally agreed that it is very important to distinguish among differing monitoring objectives in setting expectations and clarify management questions that monitoring should address during the design process.

For additional context, a workshop participant has characterized their views on how MS4 programs has evolved—including overall conditions, approaches, and lessons learned—since the early 1990s (see Table 3 on the following pages). This is intended to provide a general point of orientation to provoke thought and further discussion. It does not attempt to capture the status or changes in all programs nationwide.

Table 3. General observations on the evolution of MS4 programs.

	Early Generation Permits (1990s)	Middle Generation Permits (2000s)	Recent Generation Permits (2010s)
Overall Conditions	• Programs had limited knowledge of system assets, and there were few known water quality drivers to direct program implementation.	• System assets were better known, and there was increasing awareness of the need to address specific water quality issues (often through TMDLs) and to begin iterative program improvements. • Newer data management tools were starting to be used and some information on BMP effectiveness was becoming available.	• There is more focus on specific POCs, largely driven by TMDL provisions in MS4 permits. • There is more concern about asset management and long-term maintenance of system assets. • There is a broader focus on stormwater impacts and value beyond water quality (e.g., water supply augmentation, flood risk, urban amenities/climate impacts). • New automated and sensor-based monitoring methods can enable different monitoring designs.
Approaches	• Monitoring efforts were mainly focused on characterizing flows from the system and establishing baseline monitoring data for urban water quality conditions and trends. • Sampling was required for a few storms per year, with little to no sampling during dry weather. • Sampling was rarely conducted from MS4 outfalls; instead, it was done at convenient locations in the lower parts of watersheds to characterize "mass emissions" from all upstream MS4 discharges (often comingled with other sources and infiltration). • Permittees typically designed their own monitoring programs. • Permittees carried out paper reporting of water quality data and other program activity measures (e.g., inspections, street sweeping) through qualitative descriptions and/or semi-quantitative information.	• More elaborative MCM requirements and narrative requirements to meet water quality standards (WQS) were included in permits. Some permits included numeric triggers or action levels for POCs and requirements for low impact development approaches for new/redevelopment. • Some permits began to use surrogate indicators (e.g., flow retention, impervious cover) to reduce flows and pollutant loadings and protect receiving waters from geomorphic impacts. • Monitoring efforts were mainly focused on receiving waters (rarely outfalls) to determine whether WQS were being met and whether MS4s were causing or contributing to exceedances. • Permittees continued visual inspections of assets, BMPs, and dry weather flows and documented their occurrence in annual reports. There was rarely an analysis of their effectiveness.	• Permits include more specific water-quality-based requirements, often connected to TMDLs. • Permit structure varies depending upon whether goals are expressed in terms of outcomes (numeric limits or triggers) or activities (BMP systems based on analysis of needs). • Models are increasingly used to inform long-term program design and predict necessary control levels. • MCMs remain but, in some instances, focus on a subset that are viewed as more effective. • Adoption of asset management allows for operations and maintenance (O&M) activity reporting and a determination of optimal asset inspection and maintenance schedules. • There is less of a focus on basic water quality trend monitoring in receiving waters and more of a focus on representative outfall monitoring to help evaluate causation. • There is an increasing use of automated samplers but in limited locations.

	Early Generation Permits (1990s)	Middle Generation Permits (2000s)	Recent Generation Permits (2010s)
Lessons Learned	• Monitoring program designs rarely enabled key management questions (including compliance questions) to be answered based on the collected data. • Insufficient data was collected to detect pollutant trends in receiving water or distinguish among contributing land uses or geographical areas. • There was insufficient evaluation and reporting to ensure that stormwater controls (e.g., post-construction BMPs) were installed and properly maintained. • There was insufficient data or analysis to evaluate effectiveness of MCMs or other activities/BMPs in addressing specific water quality concerns.	• There was still insufficient data collected to detect pollutant trends in receiving water or distinguish relative contributions from different land uses, geographical areas, or individual permittees. • Monitoring designs did not support robust statistical analysis or provide a link between receiving water impacts and specific MS4 discharges (i.e., unable to answer the key question of whether the MS4 was causing or contributing to a WQS exceedance). • There was still insufficient data and analysis on BMP effectiveness to determine whether installed BMPs were resulting in the intended benefits. • Reporting and program evaluation still did not thoroughly address the effectiveness of MS4 programs in creating the desired water quality outcomes.	• Improvement is still needed to evaluate the effectiveness of activities performed under the MCMs. • In many cases, program implementation and monitoring requirements continue to mount while few are removed from permits. • New sensor technologies are not widely being used in monitoring program design. • Much receiving water and outfall monitoring still does not facilitate source analysis, compliance evaluation, or effectiveness evaluation. • There is a need to better understand how increasing reliance on modeling affects monitoring and reporting needs. • Modeling capacity and monitoring design will need to evolve to better account for non-water-quality intended benefits (e.g., water supply augmentation through infiltration, reduced flood potential, heat island impact reductions).

2.3 Existing Assessment/Evaluation Efforts and Resources

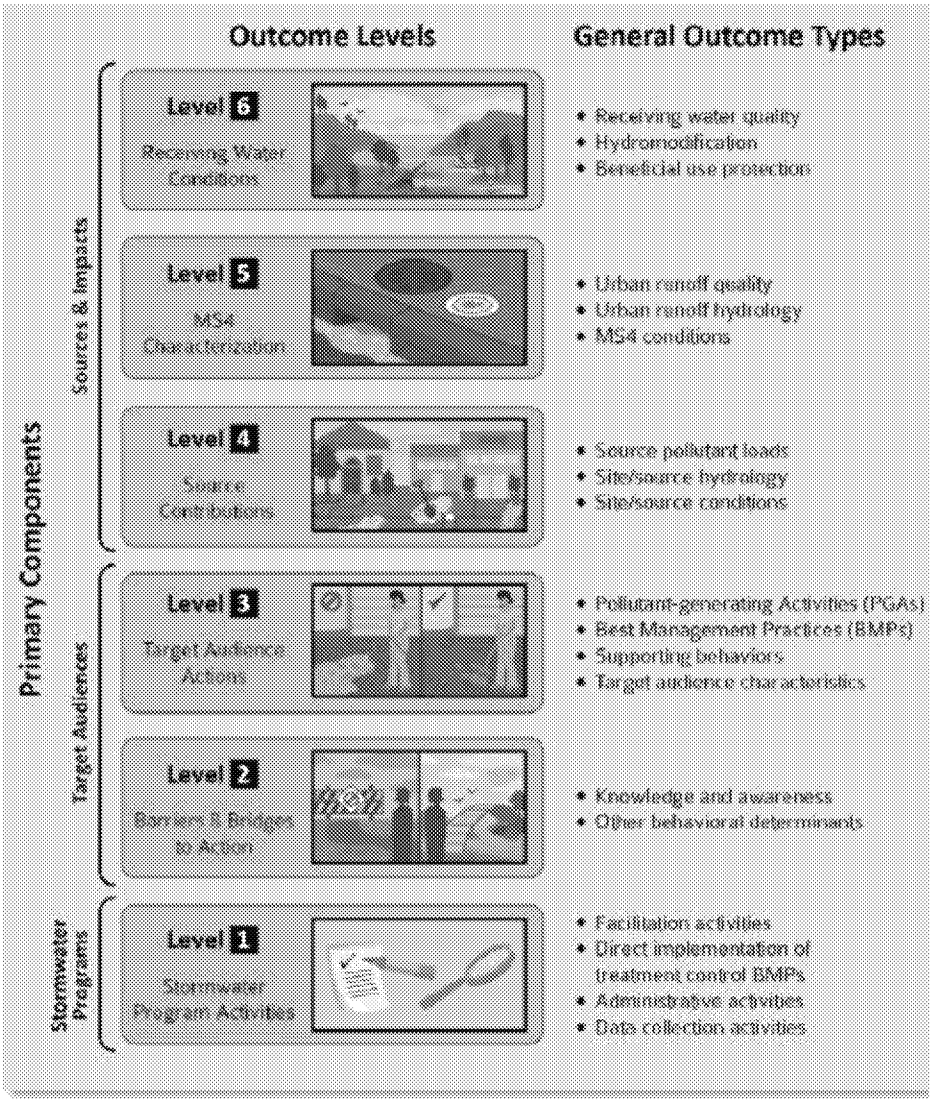
Since the MS4 program began, several entities have articulated potential improvements for program monitoring, evaluation, tracking, and reporting approaches. Even so, there is still a clear need for more concise and reproducible approaches to monitoring and evaluation that yield actionable information with links to water quality outcomes. Further, additional training for permit writers and permittees is needed to build overall capacity relating to monitoring and evaluation strategies.

Among the existing resources are the following:

- **EPA Region 3**'s *Evaluating the Effectiveness of Municipal Stormwater Programs* describes a process of goal setting in stormwater management programs (SWMPs), matching evaluation to management goals, evaluating SWMP effectiveness through a combination of program operations (e.g., activities), social indicators, and water quality monitoring. The excerpt below displays an example of this process.

  > "Evaluation of the effectiveness of a SWMP must relate directly to its goals. Two central questions are: *Are we meeting the municipal SWMP goals?* and *Are we meeting NPDES stormwater regulatory requirements?* If a goal is to keep a swimming beach open, it is often necessary to determine the extent to which water quality criteria for bacteria are being met. If a goal is to reduce nutrient loads by 40% from a watershed, it is then necessary to measure nutrient loads and compare measured loads against the goal.
  >
  > "Meeting your water quality goals is the ultimate sign of program success, however, meeting programmatic or social goals can also be indicators of a successful program. Information on how these goals are met will serve as critical feedback in the iterative process of stormwater management" (EPA, 2008).

- The **California Stormwater Quality Association** (CASQA) has also done significant work related to MS4 program effectiveness assessment and monitoring since the early 2000s. CASQA's most recent guide, *A Strategic Approach to Planning for and Assessing the Effectiveness of Stormwater Programs*, is a comprehensive 500-page reference intended to "establish specific 'how to' guidance with examples for managers in planning and assessing their MS4 programs" (CASQA, 2015). The document introduces six key outcome levels that provide "structure and measurability to evaluate and improve Stormwater Management Programs over time." The outcome levels (shown in Figure 2, below) provide a basis for discussion of how progress can be measured for MS4 program elements through monitoring or other means. This is an important resource to consider while developing a vision for the future of stormwater monitoring. CASQA also developed a *Program Effectiveness Assessment and Improvement Plan Framework*, an approach and format for permittees to assess and document MS4 program effectiveness based on their guidance document. Many MS4 permittees in California are required to use this, or a modified process, to perform effectiveness assessments.



Graphic from CASQA, 2015; included with permission

Figure 2. CASQA stormwater quality outcome levels.

- The **Southern California Stormwater Monitoring Coalition** (SMC), a collaborative effort with 14 member agencies (both regulated and regulatory), focuses on developing resources and tools for its members to "better understand stormwater mechanisms and impacts" and help "effectively and efficiently improve stormwater decision-making" (SMC, n.d). The SMC is further discussed later in this report.
- **EPA**'s *MS4 Program Evaluation Guidance* is a guidance document developed for state and NPDES permitting authority staff to evaluate compliance and effectiveness of MS4 programs. This document has served as the basis for compliance audits since its publication. The document notes that "the findings of the MS4 evaluation should not be based solely on the level of achievement of measurable goals. It is important, however, that the permittee's SWMP includes the use of measures to assess progress towards meeting goals that benefit water quality and not rely on 'bean-counting'" (EPA, 2007).

- **The California State Water Resources Control Board**'s *Guidance for Assessing the Effectiveness of Municipal Storm Water Programs and Permits* was developed to help both the state and regional water boards assess the effectiveness of the stormwater programs implemented by local agencies. The document incorporates CASQA's outcome levels in its process and "lays out a framework for assessing the effectiveness of MS4 program implementation as a whole, rather than looking at the individual programmatic elements" (CASWRCB, 2010).
- **The Center for Watershed Protection**'s *Monitoring to Demonstrate Environmental Results: Guidance to Develop Local Stormwater Monitoring Studies Using Six Example Study Designs* presents designs to help communities develop monitoring studies that will improve local stormwater programs (CWP, 2008).

Programs across the country currently fall in different places along the continuum of program implementation. There remains a need to improve and tailor monitoring, evaluation, tracking, and reporting approaches to better determine the effectiveness of different program actions and strategies and facilitate adaptive management over time.

2.4 Conceptual Effectiveness Assessment Framework

Though different terms are used across the country—reflecting real differences in program requirements and approaches—there are relevant general concepts that can broadly be viewed as "monitoring, evaluation, tracking, and reporting."

"Monitoring, evaluation, tracking, and reporting" is how MS4 programs:

1. Pose key management questions to answer through monitoring and evaluation.
2. Sample stormwater runoff and/or receiving waters.
3. Document and evaluate implementation of program activities and BMPs.
4. Synthesize and analyze results.
5. Track implementation actions and effectiveness.
6. Report to permitting authorities.
7. Make program changes in response to effectiveness assessments.

Together, these steps constitute a general program assessment framework that should help with decision-making and adjustment by local program managers and compliance evaluation and permit adjustments by permitting authorities. To gain a more comprehensive view of a program's effectiveness, many workshop participants expressed a need to tie activity tracking information (i.e., non-water-quality data) with water quality data obtained through monitoring (e.g., routine monitoring, special studies). Over time this integrated dataset could be tracked and assessed to identify a program's function and effects, and a permittee could report this information and lessons learned as needed (or requested by the permitting authority).

Figure 3 illustrates the relationship between these different types of information and actions, emphasizing integration of water quality monitoring with program implementation activities. Many MS4 programs implement parts of this framework; however, few conduct fully integrated analyses of program effectiveness that serve as the basis for compliance evaluations and program improvements. Workshop participants recognized that this framework represents a vision that will

be challenging for many MS4 permittees to implement—but they noted that many permittees continue to implement their existing programs with little understanding of whether they are effective. By building understanding of, and capacity to implement, more integrated assessment approaches, communities should be able to improve how they collect and use data and information to assist program improvement.

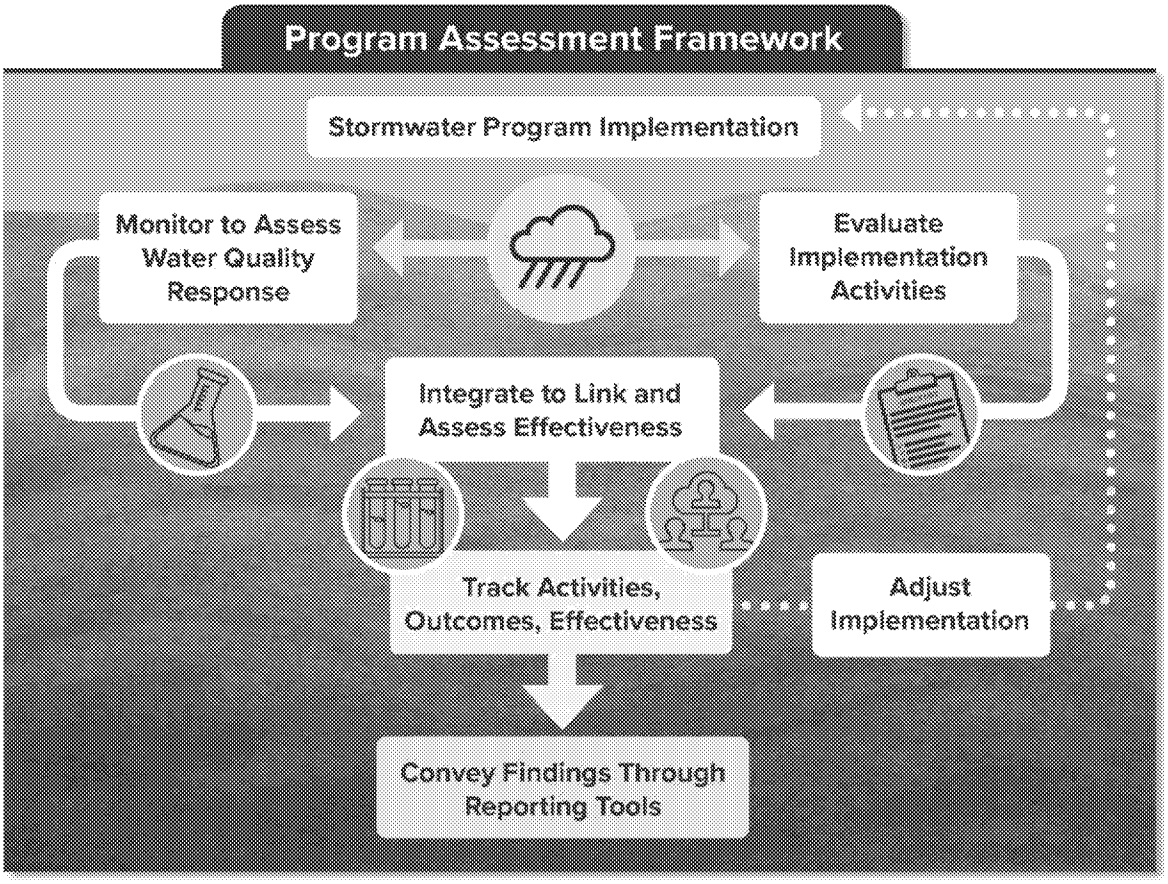


Figure 3. Conceptual program assessment framework, highlighting the link between water quality monitoring and evaluation of implementation activities to inform adjustments to program implementation.

3 Recommended Program and Permit Improvements

During the workshop, facilitators encouraged participants to identify tangible ways to improve the design and implementation of (1) monitoring and evaluation tools to assess program effectiveness and (2) tracking and reporting approaches that enable better use of available monitoring and evaluation information. These conversations generated a wide range of recommendations that can be organized under the following broad headings:

Photo: EPA

- **General capacity building and program support** (Section 3.1)
- **Improving permitting strategies** (Section 3.2)
- **Making outfall and receiving water monitoring more discriminating to inform program management** (Section 3.3)
- **Improving our ability to quantify effectiveness—approaches to link water quality outcomes to actions** (Section 3.4)
- **Improving program tracking and reporting** (Section 3.5)

Together, these discussions and recommendations are ultimately intended to spur the creation of a better overall program assessment and adaptation framework that will help local program managers across the country. The set of recommendations in this report is not definitive nor is it exhaustive; rather, this report is intended to inspire further discussions and follow-on actions. References to select projects or organizations are incorporated throughout to serve as case studies and examples of related efforts.

3.1 General Capacity Building and Program Support

While approaches to monitoring, evaluation, tracking, and reporting can be viewed in their own lanes, they are intrinsically linked and, to some degree, need to be considered collectively to identify meaningful improvements. Workshop discussions often focused on this holistic view and resulted in several overall recommendations to build integrated capacity. Collectively, the following strategies could improve overall MS4 program effectiveness and water quality outcomes.

3.1.1 Develop a Vision for the Future of Stormwater Monitoring to Improve MS4 Program Efficiency and Effectiveness

During the workshop, participants identified a lack of a central vision for why local programs perform monitoring—what questions we need to answer now and into the future—and for how monitoring efforts relate to program evaluation, tracking, and reporting. They highlighted significant inefficiencies in how these activities are typically carried out and noted potential for improvement with benefits for local programs, regulators, and water quality. Notably, participants expressed concern that many municipal stormwater monitoring efforts are resource-intensive and yield little actionable information for management decisions or generate the same information year after year.

Some participants also emphasized an acute need for models to enhance program capabilities for planning and program assessment; otherwise, water quality monitoring across large geographic areas and time scales can be resource-prohibitive. However, along with increased model usage comes a need for increased water quality monitoring data to inform and validate models.

Participants discussed what they envisioned to be key attributes of a more effective approach to monitoring and how it may intersect with other evaluation, tracking, and reporting efforts:

- Clear management questions related to water quality outcomes and activity implementation.
- A process for conducting effectiveness assessment that is tailored to the program element and the management questions being asked.
- Use of improved monitoring designs (location, scale, frequency, methods) to detect a "signal" or change in pollutant loading in stormwater or receiving waters for POCs.
- Monitoring efforts that complement activity tracking and assessment to better evaluate effectiveness of treatment or source controls (e.g., are they implemented correctly, receiving proper maintenance, and operating as expected?) and improve the basis for assessing cause and effect.
- Documented monitoring and evaluation designs coupled with identification of program modifications envisioned to improve effectiveness, inform program adjustment and new stormwater management initiatives, and achieve intended outcomes.

Photo: U.S. Army Corps of Engineers

As noted above, workshop participants identified pollution reduction, water quality protection/improvement, enhanced public awareness, and behavior changes as some key elements of program effectiveness. To achieve these outcomes and guide program implementation, workshop participants also noted a need for clear program performance metrics (further described below in Section 3.1.3).

Participants also recognized the need to distinguish between desirable assessment approaches that are reasonably well understood (but poorly disseminated and supported) and approaches that would benefit from further research and development. There was strong agreement that more needs to be done to train practitioners in the use of new monitoring, evaluation, and integrated assessment methods. Workshop participants also stressed that more basic research is necessary to develop new methods and validate their use in new settings and to address different pollutant types and hydrologic settings.

3.1.2 Develop a Guide to Monitoring and Evaluation to Better Serve MS4 Programs

Various approaches to monitoring and evaluation are used across the country. As described above, some involve a broader-scale, state-run surface water monitoring program that is somewhat associated with local MS4 programs; others involve a mix of receiving water and outfall monitoring and activity tracking and evaluation at the local jurisdiction level; yet others are implemented in

One hundred percent of pre-workshop questionnaire respondents agreed that *"Monitoring designs must go beyond just data collection methods to include data management, data analysis, and reporting formats that clearly link data collected with*

smaller watersheds to evaluate the effectiveness of specific types of stormwater control and treatment practices.

Workshop participants discussed a need to identify the range of effective monitoring approaches used and how they associate cause and effect. Further, some participants suggested using this effort to identify successful designs to inform a national-level guide on monitoring and assessing program effectiveness. This could promote consistency across the national MS4 program and enhance efficiency in local program implementation and efforts by regulators during permit development and compliance review. (An example of issues caused by inconsistency: one participant described an evaluation which determined that 34 stormwater monitoring groups in southern California could not develop common monitoring questions due to differences in study designs, methods, or data management systems.)

The proposed guide could be informed by existing resources on monitoring and effectiveness, with help from the entities involved in those resources' development and ongoing monitoring design efforts. Workshop participants suggested the guide should include the following elements:

- Framing key monitoring/evaluation questions and designing approaches to fit the questions. This could include alternative program designs with advice on assembling the components (e.g., receiving water, outfall, and in-system water monitoring; BMP effectiveness evaluation; activity tracking of treatment and source controls; modeling) to inform assessment of the overall program and demonstrate effectiveness. This should show how to build a sound analytical framework up front to demonstrate why a set of approaches will likely succeed in assisting program management and defining or tracking compliance and effectiveness.
- Considerations for adapting monitoring/evaluation questions over time, with a reasonable limit on the creation of new questions.
- Examples of successful local approaches that better associate monitoring/evaluation design with program effectiveness, compliance assessment, and the ability for program managers to make management decisions.
- Suggested evaluation methods to assess BMP effectiveness over time.

Example Monitoring/Evaluation Questions

- *Are BMP systems now implemented in Sample Creek watershed sufficient to meet TMDL-based sediment limits? If not what additional BMPs are needed?*
- *Which land uses or sub watershed areas are principally responsible for copper loading?*
- *Have specific public education efforts resulted in measurable reductions in trash discharges? How much?*

- Available monitoring technologies and best practices that clearly link the monitoring objectives with the experimental design, including all aspects of data collection, data management, data analysis, and reporting formats.
- Compiling monitoring program costs to help show the wide range of program expenditures, how monitoring data are used to inform program decisions, and how to better articulate the value of the data.
- Explanations of modeling approaches and how they can relate to monitoring and adaptive management.

Beyond the monitoring design elements, select workshop participants suggested that clearer direction is needed for the technical aspects of monitoring as well. Specifically, standard protocols and references are needed for appropriate equipment, protocols, site selection, sampling frequency, data management/analysis, and quality assurance. Program evaluators (e.g., regulators) also need guidance in assessing the technical "quality" of discrete monitoring program elements.

3.1.3 Establish Key Performance Metrics (Activity- and Outcome-Based) for MS4 Programs

Workshop participants agreed that clear performance metrics need to be established to enable meaningful MS4 program evaluation and monitoring. They discussed ideas for developing metrics that are valuable and can help define measurable outcomes. Several people suggested compiling possible metrics (from prior efforts such as rulemakings or new metrics), researching the efficacy of different metrics, and synthesizing the information to spur progress in this area.

Ninety-six percent of pre-workshop questionnaire respondents agreed that *"Performance metrics need to be established in concert with improved monitoring designs and methods"* and that *"Metrics should enable evaluation not just of what was done, but also of whether those actions were effective."*

It was noted, however, that it may not be possible to identify meaningful performance metrics with measurable outcomes for some MCM activities. For example, it has proven difficult to identify appropriate metrics for the effectiveness of public outreach and facility inspection programs. Further, participants indicated that there should be specific considerations for the differences between treatment control BMPs (e.g., permanent stormwater controls) and source control BMPs (e.g., facility inspections) in setting performance metrics.

During a facilitated exercise, workshop participants brainstormed possible overall metrics of program performance that go beyond tallying activities or "bean counting":

- Percent of impervious areas addressed for stormwater management.
- Condition or "cleanliness" of streets as an indicator of potential pollution from runoff.
- Percent of impervious surface areas directly connected to the storm drain system.
- Modeled volume of flow to the storm drain system used as a surrogate for pollutant contributions.
- Percent of waterbodies in a community that are fishable and swimmable.
- Loss of beneficial use of a waterbody (e.g., beach closure downtimes).
- Measured level of awareness of citizens regarding stormwater pollution and the community's program.
- Increasing number of illicit discharges reported annually; indicating heightened awareness.
- Budget for stormwater infrastructure improvements.

The **American Water Works Association** has a benchmarking program for drinking water programs; no analogous program exists currently in the stormwater sector.

The **National Municipal Stormwater Alliance** (NMSA) is currently working with the **American Society of Civil Engineers** to develop a national stormwater "report card" since data on program performance is lacking.

Participants also discussed several MCMs and whether clear links could be drawn between program activities and

measurable water quality outcomes. It was easier to envision links for water-quality-based efforts such as stormwater management in new development and redevelopment through BMPs; activities like public education and outreach, construction site inspections, and outfall screening proved more challenging. One workshop participant characterized it this way: "There is an obvious desire to seek and set *outcome* rather than *output* performance metrics. However, MCMs are primarily or essentially low-cost prevention actions, which don't lend themselves to measurable water quality outcomes."

Questions remain: What are meaningful performance metrics for MS4 programs overall, as well as the individual program elements and MCMs? What mix of output and outcome metrics can guide programs in developing monitoring programs, assessing effectiveness, and performing tracking and reporting? Participants recognized the difficulty of making these links but emphasized the importance of better addressing this challenge.

Workshop participants suggested that more work will be needed to compile, evaluate, and disseminate information about existing performance metrics. For many types of program activities (e.g., public participation and some other MCMs), further research will be needed to develop and validate new metrics before implementation.

3.1.4 Identify Ways to Leverage Existing Data Sets to Improve MS4 Program Management Decisions

MS4 programs have collected, documented, and reported a significant volume of data on implementation and monitoring over the years. While some permittee representatives at the workshop lamented the amount of resources typically involved in tracking and reporting, they also acknowledged that the vast amount of data collected has the potential to inform program management decisions. For example, existing data sets on illicit discharge locations and types could be analyzed in concert with outreach information and awareness levels to identify trends and better direct program resources to address illicit and unpermitted discharges. In addition, many permittees have gathered significant water quality monitoring data; these data could be explored further to find more ways to tell the story of what is happening in a waterbody or watershed.

California's **Storm Water Multiple Applications and Report Tracking System** is a web-based platform for stormwater program (construction, industrial, municipal) permit applications and reporting. Workshop participants suggested that data in this system could be used to help inform some municipal stormwater program functions and priorities, especially as they relate to oversight of construction sites.

EPA's **NPDES Electronic Reporting Rule** (E-Reporting Rule) requires entities to electronically submit specific permit and compliance monitoring information instead of filing paper reports beginning in 2020; this presents a key opportunity to collect information, analyze data, and compare the results.

Workshop participants suggested that better data analytics tools, processes, and guidance need to be developed for program managers to (1) turn existing data into information, (2) use the information to more confidently make program management changes, and (3) collect better data to continue to feed the process. One inherent issue is that local programs use various mechanisms for tracking data and not all programs track the same types of data. This issue will need to be considered and addressed, and the development of new tools with tangible uses could encourage more consistency in data collection techniques.

Participants also discussed the possible use of data and information in annual reports submitted by local programs in a state or region. They noted that many NPDES permitting authorities do not have resources to fully review the significant quantity and volume of annual

reports submitted; however, those reports may contain some intermediate indicators of program performance that could readily be identified to provide feedback to permittees.

Trends observed in a group of annual reports in a state or region could be used to inform permittees of common issues and areas requiring more clarification or support to yield better program implementation. Many states or regions have municipal stormwater management groups that meet periodically and could serve as a forum for sharing this type of information—the issue is *who* will review these reports to identify common issues and trends. Though regulators are typically looked to for reviewing annual reports to determine compliance with implementation and reporting requirements, without full resources for regulators to fulfill this role it may be worth considering if other groups (e.g., nonprofits, university research students, watershed groups) could provide a routine review and analysis of publicly available annual reports. These groups could work with regulators to develop an approach that would bring more utility to the annual reports produced by permittees and help buoy program implementation in a state or region.

3.2 Improving Permitting Strategies

Eighty-eight percent of pre-workshop questionnaire respondents agreed that *"Stormwater quality monitoring has been largely ineffective in assisting compliance evaluation, problem targeting, and program improvement."*

As noted above, many permitting authorities and permit holders believe there are significant opportunities to improve approaches to municipal stormwater program monitoring, tracking, evaluation, and reporting, and these improvements may be directed or better incentivized through permitting strategies. Workshop participants indicated that permit writers need additional training and guidance on best practices. Example permit language would also help with implementation.

As was noted in the first workshop, MS4 permitting programs are often understaffed and have devoted insufficient resources to provide and/or update technical and policy guidance, assist permittees in program improvement, and issue timely permitting decisions and compliance actions. Provision of adequate resources for EPA and state permitting offices will be critical to facilitating improvements in permitting and program development. It was recognized during the workshop that permitting authorities bear some responsibility for improving and validating program monitoring and effectiveness assessment methods and demonstrating how they can be authorized through permit actions.

3.2.1 Improve Clarity of Monitoring and Effectiveness Permit Requirements (Including Objectives, Methods, and Designs)

Ninety-two percent of pre-workshop questionnaire respondents agreed that *"Training and outreach for permit writers, program staff, and elected officials on new methods and designs are needed to familiarize these groups with their benefits and limitations."*

Workshop participants suggested that current permit designs for monitoring requirements regularly lead to long-term monitoring at geographic scales that do not enable detection of signals for program performance or establish cause and effect between program actions and water quality conditions. Further, there is often an aversion to modifying monitoring locations for fear of losing continuity in long-standing datasets. Some of this may be due to ambiguity in permit requirements or reluctance by permit writers to change requirements; it may also be an attempt to put the onus on permittees to develop monitoring programs without guidance to steer them toward more

efficient and effective designs. Many permits also give equal weight to tracking and reporting for all aspects of program implementation, which can lead to highly resource-intensive efforts by local programs to record, compile, and summarize information for annual reporting.

Participants identified an overall need for permitting authorities to improve the clarity of monitoring and evaluation permit requirements and to use thoughtful methods/designs that will yield actionable data. Further, some participants noted that permits may be able to provide choices or flexibility for monitoring approaches and help incentivize better designs. Flexible permit requirements can support adaptation of monitoring to evolve with program needs, with the potential questions to be addressed changing over time. For such an approach to succeed, it may be necessary to discontinue some monitoring efforts to redirect resources to more pertinent or valuable monitoring.

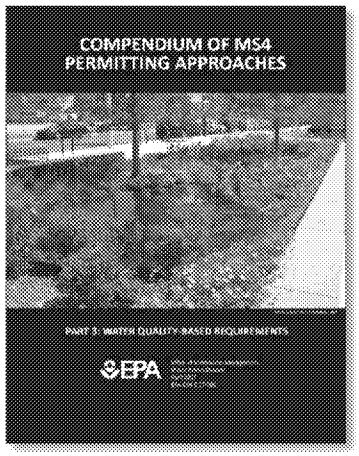


Figure 4. Water-quality-based requirements compendium that includes several monitoring program examples.

To help permitting authorities understand various approaches being used across the country, EPA developed a compendium series of MS4 permitting approaches. Part 3 focused on water-quality-based requirements and included a section describing monitoring and modeling approaches related to TMDLs and water body impairments. While this compiled information is helpful for understanding some relevant monitoring case studies, it does not evaluate what aspects of the efforts were successful or unsuccessful, identify benefits and limitations, or provide advice on what approaches are appropriate for certain scenarios. There is a continuing need to identify different approaches and extract the lessons learned and best practices to inform efforts by others in the sector.

California's Municipal Regional Stormwater NPDES Permit for the San Francisco Bay area (adopted 2015) features a monitoring program that is driven by management questions, allows for scaling up to larger areas (county-wide or region-wide), accounts for different types of monitoring (e.g., receiving water status monitoring, POC monitoring), and includes stressor/source identification projects in response to monitoring findings. The permit provides directions on various methods to obtain relevant information to drive management actions. The monitoring requirements have attempted to provide a balance between directives and flexibility to allow permittees to seek optimum benefit from monitoring with available monitoring resources.

Note that increased clarity and better designs may not be possible until some of the abovementioned recommendations for capacity building and program support are followed. Training and other support tools will be needed to help boost permit writers' understanding and ability to improve approaches to monitoring, tracking, evaluation, and reporting.

3.2.2 Create a Pathway in Permits to Make Special Studies or Targeted Monitoring More Impactful

NPDES permits often include special studies or additional monitoring requirements to help gather data needed to explore identified issues and support future permit development. The *NPDES Permit Writers' Manual* notes that permits should set reasonable schedules for completion and include any requirements for these studies, such as special sampling or analytical procedures (EPA, 2010b).

Workshop participants indicated that many long-term or special studies have been completed, especially in California, but there often isn't the opportunity to apply the lessons learned from them. They urged that *if* special studies are required, there should be a clear pathway in the permit to apply what is learned. Some noted that a special study should be designed to address a specific topic; it should be short-term, with a discernible beginning, middle, and end—a process to obtain the answer to the question, apply the knowledge, make program and/or permit changes, and then move on.

Some participants described special studies as an opportunity to be more targeted in scope. They would not necessarily have to relate to overall program effectiveness; rather, they could be used to improve program operations. For example, a special study could be a testing ground for exploring the use of innovative technologies, sensors and screening devices, or remote sensing on smaller scales before a program makes a significant investment and a permit writer moves any associated requirements into the core permit. There could be a tiered approach that links the research field to the regulatory community to help field test new technologies.

The **Southern California Stormwater Monitoring Coalition**, a collaborative effort with 14 member agencies (both regulated and regulatory), has conducted more than 20 projects over the past 14 years with a focus on topics such as (1) understanding runoff mechanisms and processes, (2) building monitoring infrastructure, (3) optimizing management strategies, and (4) assessing impacts and improvements in receiving water. While each SMC agency has spent less than $500k on these efforts over the past 14 years, the members have leveraged these investments through in-kind contributions and grants to create a total investment of more than $17 million. According to an SMC member, each of the projects undertaken by SMC has led to changes in the way the member agencies manage stormwater or implement NPDES permits.

One workshop participant discussed how special studies could more effectively be viewed within the construct of an overall monitoring approach.

- Special studies should explore very specific, complex questions. If the questions are answered, then the benefits could extend far into the overall MS4 program.
- Sophisticated equipment and protocols may be needed for special studies, though the outputs should be simple and applicable to help a program adapt.
- Not all permittees should be asked to perform special studies—there should be fewer, more specific special studies to answer questions facing the program.
- Some questions (e.g., BMP effectiveness) may not be appropriate to address through permits; outside parties should be engaged to help.

In summary, participants saw an opportunity to improve how the results of special studies are applied to not only the programs that conducted the studies but, in some cases, the larger community of MS4 programs. However, at present, there is a gap in bringing this knowledge to the broader program. A dedicated institution (e.g., an academic or research organization) may be best suited to serve as a hub to gather, evaluate, and disseminate relevant information from such studies. For example, the original text of H.R. 3906 (the Innovative Stormwater Infrastructure Act of 2018) proposed the establishment of "centers of excellence" for innovative stormwater infrastructure. Although this proposal was dropped from subsequent versions of the bill, workshop participants found this idea compelling. More broadly, workshop participants emphasized the need for a focused national conversation about stormwater-related research needs and priorities.

3.2.3 Evaluate Whether Lack of 40 CFR Part 136 Approval Presents a Barrier to Implementing New Technologies for Water Quality Sampling and Analysis

New technologies for measuring water quality have proliferated, with an increasing trend toward continuous, real-time sensors. In addition, new "bio" technologies (e.g., genetically engineered bacteria that fluoresce when they contact metals) are being developed to detect the presence of certain constituents. Approved sampling and analysis methods at 40 CFR 136 do not necessarily include these new methods, which workshop participants identified as a potential barrier to their use. The need to validate new technologies was identified as hindering both technology commercialization and the ability of MS4 program managers to confidently move forward with using new technology.

As an action item, workshop participants suggested inventorying currently used non-CFR-approved technologies and known instances where programs have elected not to use a new monitoring technology because it is not an approved method. Where possible, it would be helpful to identify avenues to address impediments to those technologies' use—rule changes, use of existing procedures to approve new technologies on a case-by-case basis, or other creative uses of the technologies.

The **Southern California Stormwater Monitoring Coalition** has used alternative non-CFR-approved methods to offer cheaper and faster sampling techniques. For example, they have used genetic analysis technologies for (1) rapid fecal bacteria measurement, (2) pathogens measurement, and (3) measuring algae in streams.

Representatives from environmental organizations at the workshop explained that they often employ new technologies that are not approved by 40 CFR Part 136, as they are not restricted to permit-approved methods for their research. These organizations may belong to a sector that may be more willing to test new approaches, then share them with the broader stormwater management community.

Additional discussion about envisioning uses for sensors and other new technologies is included in Section 3.3.2 below.

3.3 Making Outfall and Receiving Water Monitoring More Discriminating to Inform Program Management

Municipal stormwater programs are unique among sources under the NPDES program because there are often many discharge points from a storm sewer system and relatively little direct treatment before discharge. A wide variety of external factors—many beyond the control of the permittee, as shown in Figure 5's example below—contribute pollutants to receiving waters, not just stormwater runoff. As well, MS4s vary substantially in size, complexity, and management challenges. A point source such as a wastewater treatment plant operates in a much more controlled environment with a more obvious approach for pollution reduction, monitoring, and attributing permittee actions to water quality responses.